ABUNDANCE AND DISTRIBUTION OF PEARY CARIBOU AND MUSKOXEN ON BANKS ISLAND, NWT JUNE 1989

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DEPARTMENT OF RENEWABLE RESOURCES

GOVERNMENT OF THE NORTHWEST TERRITORIES

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File Report No. 106

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ABSTRACT

A stratified strip transect survey of Banks Island, NWT was conducted between 22 and 28 June 1989. The survey documented distribution and numbers of Peary caribou (Rangifer tarandus pearyi) and muskoxen (Ovibos moschatus). The total number of non-calf caribou observed on transect was 344 resulting in a population estimate of 2,600 ± 340 (SE of estimate). Densities varied from 0.02 (caribou/km^2) in the low density stratum to 0.16 (caribou/km^2) in the high density stratum on northwestern Banks Island. Mean group size, including calves was 3.6 ± 2.17 (S.D.) overall and was significantly greater in the high density area. The proportion of calves to total classified was 25.5% (118 /462). Caribou numbers have drastically declined from the 1970s.

A total of 5791 non-calf muskoxen was observed on transect resulting in a population estimate of 34,270 ± 2360 (SE of the estimate). Densities varied from 0.26 (muskoxen/km^2) in the low density areas to 1.84 (muskoxen/km^2) in the high density strata. Mean group size, including calves was 6.15 ± 4.82 (SD) overall. The proportion of calves to total number of animals classified was 12.7% (871/6632). Muskox numbers have increased since the 1970s.

TABLE OF CONTENTS

ABSTRACT iii

LIST OF FIGURES vii

LIST OF TABLES ix

INTRODUCTION 1

METHODS 2

RESULTS 6
Caribou. 6
Muskoxen. 8
Wolves. 9

DISCUSSION 10
Survey conditions and design. 10
Population characteristics. 11

RECOMMENDATIONS 15

ACKNOWLEDGEMENTS 16

LITERATURE CITED 17

Appendix A. Survey schedule and costs, Banks Island, NWT June 1989 19

Appendix B. Number of caribou observed on transect on Banks Island, NWT June 1989 20

Appendix C. Number of muskoxen observed on transect on Banks Island, NWT June 1989 23

Appendix D. Statistical procedures used to calculate the Student's t-test 28

LIST OF FIGURES

Figure 1. Transect lines and caribou strata boundaries used during the muskox/caribou survey on Banks Island, NWT, June 1989 3

Figure 2. Transect lines and muskox strata boundaries used during the muskox/caribou survey on Banks Island, NWT, June 1989 4

LIST OF TABLES

Table 1. Summary of survey information for Banks Island caribou, June 1989 7

Table 2. Summary of survey information for Banks Island muskoxen, June 1989 9

Table 3. A comparison of caribou calf percentages during aerial surveys on Banks Island, NWT, 1970 - 1989..... 12

INTRODUCTION

Numbers of caribou and muskoxen have been monitored on Banks Island (70,028 km2) since the 1970s. The caribou had declined from an estimated population size of 9,000 in September 1972 (Urquhart 1973) to an estimated 5,000 ± 910 (SE of estimate) non-calves in 1985 (McLean et al. 1986), and 4500 ± 660 (SE) in 1987 (McLean in prep). Muskox numbers have increased since the 1970s from at least 3800 in 1972 (Urquhart 1973), to an estimated 25,700 ± 2050 (SE of estimate) in 1985 (McLean et al. 1986).

Caribou and muskoxen are important resources to the people of Sachs Harbour. Caribou are taken in preference to muskoxen for personal consumption. Both caribou and muskoxen are shot by non-resident guided hunters. This provides cash revenue to the people of Sachs Harbour. Commercial muskox kills have taken place since 1981 with from 50-300 shot annually.

METHODS

The aerial survey was conducted using methods similar to the 1985 and 1987 Banks Island surveys (McLean et al. 1986, McLean 1990). For the initial survey, the island was divided into 4 relatively equal sized areas. Transect lines, aligned perpendicular to the major river drainages, were spaced 12.5 km apart to provide 10% coverage (Fig. 1 and 2). Areas of caribou and muskox concentrations were delineated subjectively from the initial survey maps and resurveyed at approximately 20% coverage using the same strip width and survey altitude.

A Cessna 185 and a Helio-Courier STOL (short takeoff and landing) equipped aircraft on tundra tires were used concurrently for the survey.

The survey was conducted at an altitude of 120 m above ground level (agl) at an air speed of about 160 kph in the C-185 and 140 kph in the Courier. Strip width was 0.6 km on each side of the aircraft for a total transect width of 1.2 km. The strip width was marked using wooden dowels taped to the wing struts (C185) or a tape marker on a wire stretched between the tie-down rings and the fuselage (Helio-Courier) according to a formula (Norton-Griffiths 1978). The strip markers were then checked against a known distance on the runway at Sachs Harbour and adjusted accordingly during several passes of each aircraft at survey altitude.

In each aircraft, the pilot navigated and marked the location

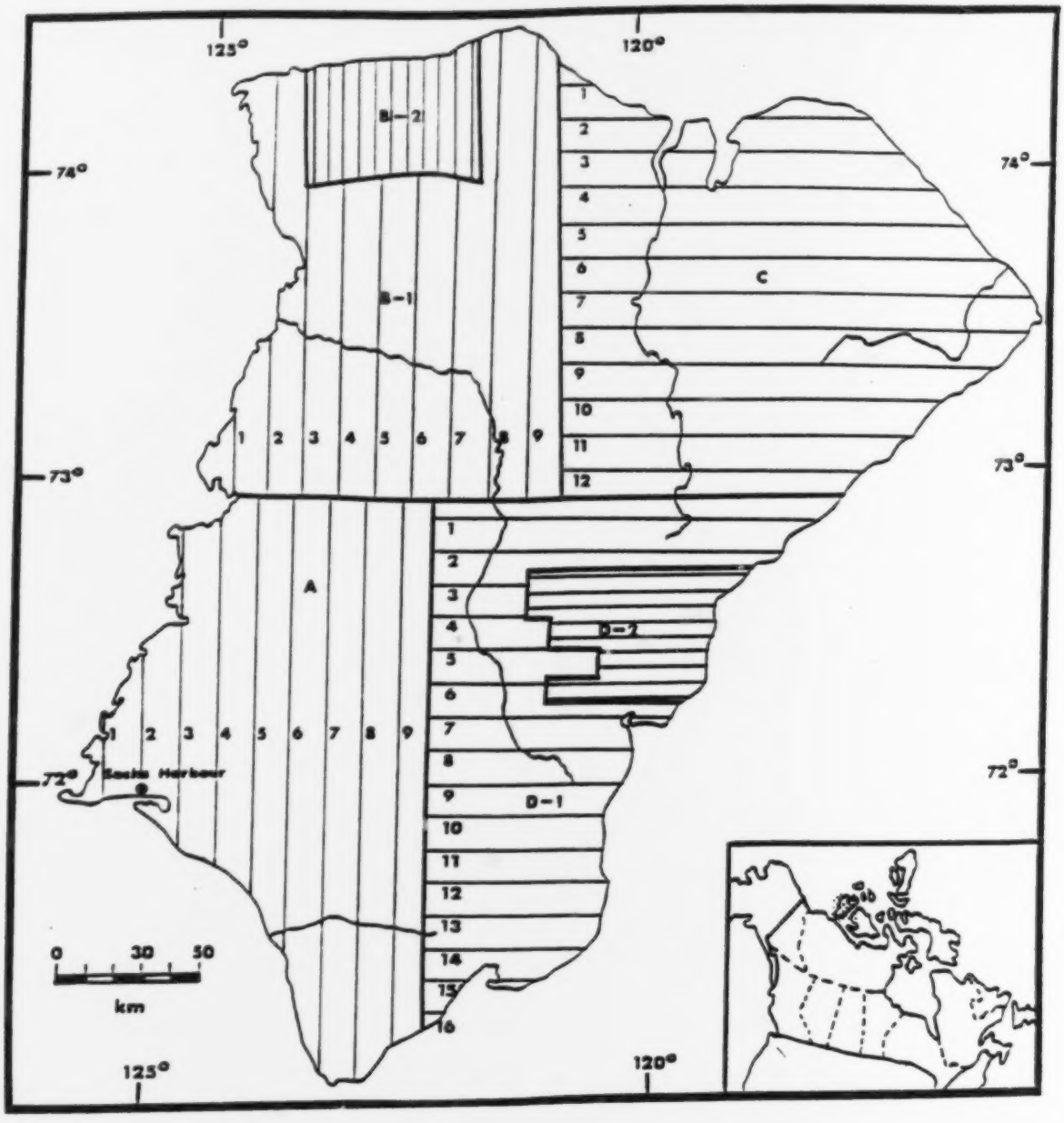

Figure 1. Transect lines and caribou strata boundaries used during the muskox/caribou survey on Banks Island, NWT, June 1989.

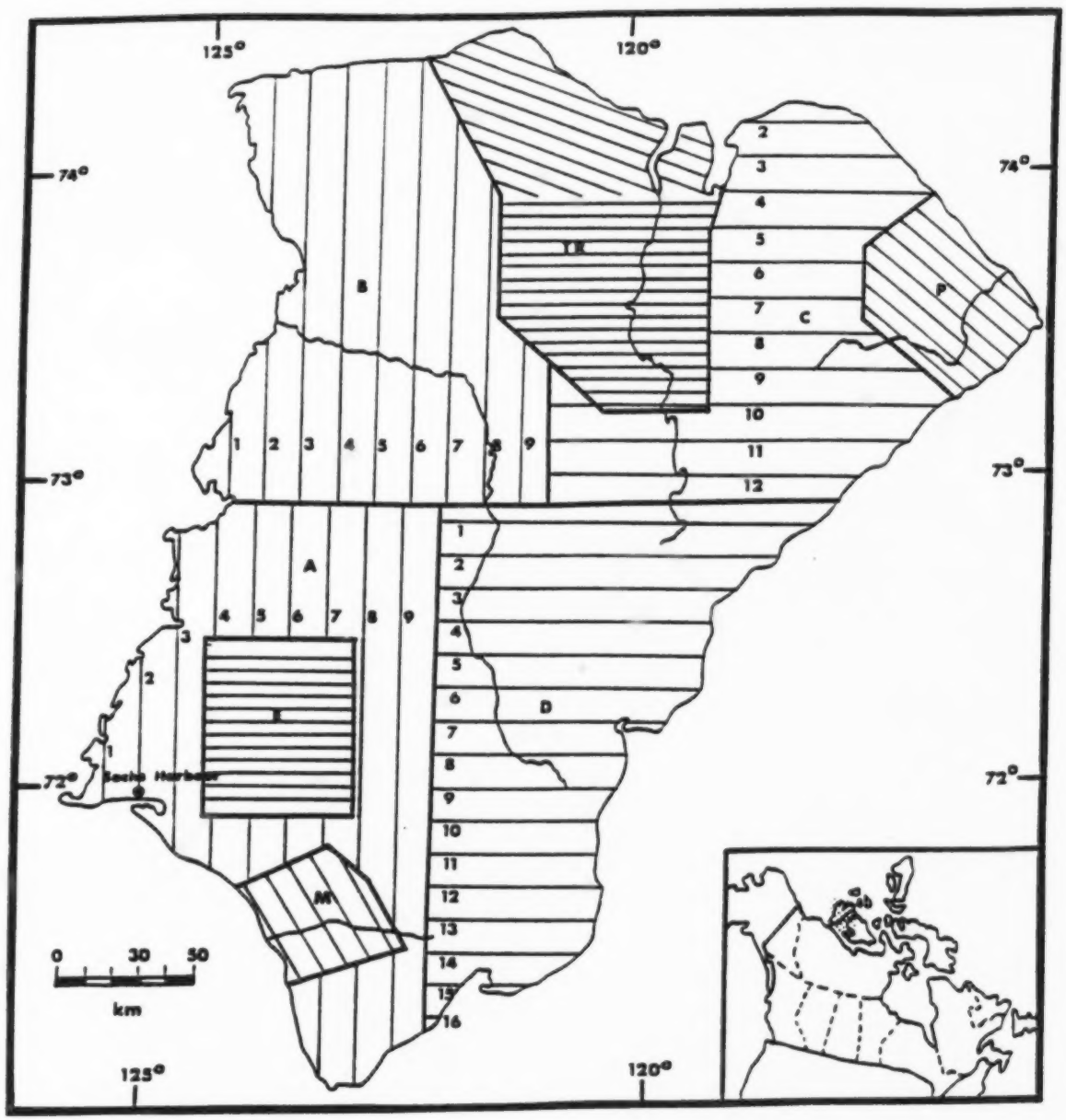

Figure 2. Transect lines and muskox strata boundaries used during the muskox/caribou survey on Banks Island, NWT, June 1989.

of animals on 1:250,000 scale topographical maps. Two observers in the rear continuously searched for and counted caribou and muskoxen older than calves observed on transect. The number of calves was counted whenever possible. If any part of a group was within the transect then the whole group was counted as being in. The information was transmitted on a Sigtronics 4-way intercom system and recorded on data sheets by the front-seat passenger who also assisted by spotting animals for the right rear observer.

Transect data were transcribed daily onto summary sheets. Descriptive statistics were calculated on an Apple IIc computer using a census data program based on Jolly (1969), method 2 for unequal sample sizes. Survey areas were calculated using a polar planimeter.

Student's t-test is used to determine the probability of two population estimates differing in size. Zar (1984:126) discusses using the t-test to test for differences in population means which Gasaway et al. (1986) extended to test for differences in population size. The statistical procedures to calculate the probability that a change occurred are provided in Appendix D.

RESULTS

The initial reconnaissance of the whole island took approximately 58 h from 22-25 June 1989. From 26-28 June, an additional 10 h were expended in the caribou high density and 33 h in the muskox high density areas. The cumulative total was 117 h for the survey (including ferry, Appendix A).

The southern half of the island was 90% snow free for the survey. Snow was still present in the higher areas of the northwest and northeast portions of the island, percent coverage varying between 10 and 80%. Ground fog prevented surveying during the evening of 24 June and the morning of 25 June.

Caribou

Caribou distribution was similar to that found in previous years. The animals were observed in small groups distributed over most of the island. Two areas of relatively high density were delineated from the initial transects of the island - one in the northwest (B-2) and the second north of Jesse Bay (D-2, Fig. 1).

A total of 344 non-calf caribou was observed on transect, including 180 in the two high density areas. An estimate of 2600 $\pm$ 340 (SE of estimate) non-calf caribou was calculated for the entire island (Table 1). Densities varied from 0.02 (caribou/km^2) in the low density stratum to 0.16 (caribou/km^2) in the high density

Table 1. Summary of survey information for Banks Island caribou, June 1989

Stratum	Area(km^2)	Pop. Est. (S.E.)	(CV)	Density (/km^2)	Mean grp size (S.E.)	Calf/ total %(n)
SW	13317	331 ± 127	0.38	0.02	3.0 ± 1.2	7.9
NW^{Low}	13444	365 ± 113	0.31	0.03	2.5 ± 0.7	14.7
NW^{High}	2030	326 ± 96	0.29	0.16	3.7 ± 2.0	25.7
NE	22301	264 ± 88	0.33	0.01	2.3 ± 0.5	9.1
SE	15961	884 ± 245	0.28	0.06	3.0 ± 1.6	23.8
Jesse Bay	2975	422 ± 73	0.17	0.14	5.1 ± 2.9	36.0
Total	70028	2593 ± 334	0.13		3.6 ± 2.2	25.5

stratum on northwestern Banks Island.

Including individual caribou and all groups for which calf and total counts were determined, the proportion of calves to total was 25.5% (118/462), and was highest in the Jesse Bay high density area, D-2 (36.0%; Table 1).

The mean caribou group size was significantly larger in the high density area (3.7 ± 2.0 (SE)) on NW Banks than in the rest of the island (low density) 2.81 ± 1.28 (SE); ($t'=6.06$; $t_{0.05[110]}=1.982$; Table 1).

Twenty-nine caribou carcasses, winter kills, were observed on transect during the survey. Extrapolating for the entire island produces an estimate of approximately 300 caribou carcasses (based upon 10% coverage).

Muskoxen

Distribution of muskoxen on the island was similar to previous years. Muskoxen were sighted in most parts of the island with few animals observed in the flat, west-central part of the island drained by the Bernard River. Four areas of muskox concentrations were identified from the initial survey - Thomsen River (TR), Parker River (P), Egg River (E) and Masik River (M, Fig. 2).

A total of 5791 non-calf muskoxen was counted on transect resulting in a population estimate for the island of 34,270 $\pm$ 2360 (SE of the estimate; Table 2). Densities ranged from 0.26 (muskox/km^2) in the low density strata to 1.84 (muskox/km^2) in the Masik River high density stratum.

The mean group size, excluding single animals but including calves was 6.15 $\pm$ 4.82 and did not differ significantly among strata. Muskox mean group size was similar in both the high (6.21 $\pm$ 4.75; n=725) and low density areas (6.01 $\pm$ 4.99; n=304; t'=0.70; $t_{0.05[1027]}$=1.96). The proportion of calves to total number of animals classified was 12.7% (841/6632; Table 2).

A total of 120 muskox carcasses was counted on transect during the survey. Extrapolating to the whole island would give a rough estimate of 685 carcasses.

Table 2. Summary of survey information for Banks Island muskoxen, June 1989

Stratum	Area(km^2)	Pop. Est. (S.E.)	(CV)	Density (/km^2)	Mean grp size (S.E.)	Calf/ total %(n)
SW	9587	3833 ± 1147	0.299	0.40	7.1 ± 5.3	12.8
NW	13026	4697 ± 1300	0.277	0.36	6.3 ± 6.6	10.9
NE	15621	5774 ± 652	0.113	0.37	5.9 ± 4.5	13.9
SE	18935	4973 ± 651	0.131	0.26	5.1 ± 3.0	12.3
Egg R	2320	2101 ± 439	0.209	0.91	7.9 ± 5.3	13.9
Masik R	1410	2588 ± 969	0.374	1.84	6.5 ± 5.1	12.0
Parker R	3050	2216 ± 271	0.122	0.73	4.8 ± 3.0	7.9
Thomsen R	6079	8042 ± 712	0.089	1.32	6.2 ± 4.8	13.6
Total	70028	34,266 ± 2359	0.069		6.1 ± 4.8	14.5

Wolves

Wolves were observed on three separate occasions. Four wolves travelling together were observed in stratum B-2. Two separate packs (2 adult wolves; 2 adults + 5 pups) were observed in the Thomsen River area, one at a den site. These observations would give an estimate of 0.07 wolves/hr. All of the obervations were off transect.

DISCUSSION

Survey conditions and design

Most of the snow had melted by the start of the survey except for drifts and some patches in high elevations. The majority of caribou were still in light winter pelage and contrasted with the bare ground.

The use of two aircraft was essential to get the survey completed in a short time. The division of the island into four parts shortened the transect lines and minimized observer fatigue. The STOL equipped aircraft also permitted landings for breaks during the survey.

Survey altitude and strip width were reduced to increase visibility of caribou relative to previous surveys. We flew lower than the 1985 and 1987 surveys (120 m vs 180 m in 1985 and 150 m in 1987). Strip width used in 1989 was narrower than in 1985 (1.2 km vs 2 km). Latour (1985) believed that sightability of caribou in July 1982 was excellent at a survey altitude of 120 m. In the July 1985 survey, the observers felt that animals were probably missed as some caribou were not detected until the aircraft was almost past them (McLean et al. 1986). Undoubtedly we missed animals in this survey as well, but have no measure of this bias.

Stratification of and the surveying of additional transects in high density areas (northwest Banks, Jesse Bay, Parker, Masik, Egg, and Thomsen rivers) reduced the variance of the final estimate. The

unstratified caribou estimate was 2800 ± 410 with a C.V. of 0.15. The caribou estimate changed slightly with the additional stratification (2600 ± 340 SE, C.V. 0.13). The unstratified muskox estimate was 41,000 ± 5470 S.E., C.V. of 0.13, and was lower with the additional stratification (34,270 ± 2360, C.V. 0.69). The level of precision recommended for the NWT is 0.10 (Heard 1985).

Population characteristics

The trend in the estimates clearly indicates a decline in numbers of caribou. The 1989 population estimate of 2,600 ± 340 (SE of estimate) is significantly lower than the July 1987 estimate (4,500 ± 660 S.E., McLean in prep., $t'=2.566$; $t_{0.05[23]}=2.069$), the July 1985 estimate (5,000 ± 910 SE of estimate, McLean et al. 1986, $t'=2.411$; $t_{0.05[36]}=2.028$;) and the July 1982 estimate (7,233 ± 998; Latour 1985, $t'=5.316$; $t_{0.05[24]}=2.064$).

The factors causing the decline in caribou are not well understood. The age of first breeding and pregnancy rates, and number of calves which survive their first winter can vary between years in Peary caribou (Thomas 1982). Little information on age and sex ratios, and calf survival has been collected. Calf percentages from aerial surveys in June-July has ranged from 14 to 25% of animals counted (Table 3). Years where a lower calf percentage has been observed may be indicative of low pregnancy rates or high calf mortality or both.

Winter snow and icing conditions, human harvest, and wolf

Table 3. A comparison of caribou calf percentages during aerial surveys on Banks Island, NWT, 1970 - 1989.

Date	% Calves	Sample Size	Reference
06/1970	19.0	1078[1]	Kevan 1974
06/1971	27.9	-[2]	Urquhart 1973
06/1972	14.3	-[2,3]	Urquhart 1973
07/1982	25.0[4]	1791	Latour 1985
07/1985	15.3	898	McLean et al. 1986
07/1987	22.6	557	McLean in prep.
06/1989	25.5	344	This study

1 Northern Banks Island only.
2 Not given in the report.
3 Calving still in progress.
4 Estimated from report, not calculated by Latour.

predation are all factors likely influencing calf and adult survival. Peary caribou as well as muskoxen are susceptible to periodic winter mortality caused by forage unavailability after severe icing or deep snow (Parker et al. 1975). Winter mortality was judged to be unusually high in the 1950s, 1969-1970 (Urquhart 1973) and in 1977-1978 (Morrison 1978).

The annual hunter caribou kill from Banks Island has been estimated at a minimum of 385 animals from July 1986 to July 1987 and 225 from January - December 1988 (Fabijan in press). This would be a harvest rate of approximately 5-8.5% of the 1987 population estimate. Residents of Sachs Harbour had a more difficult time finding caribou during the winter 1988-89 and also feel that the numbers have declined.

Mainland caribou have approximately 7-15% natural mortality in the presence of predators (Bergerud 1978, Davis et al. 1988). Mortality rates are higher in males than females (Davis et al. 1988). The extent of wolf predation is unknown on Banks Island. It is very difficult to estimate numbers of wolves based upon aerial surveys in the High Arctic (Miller and Russell 1977).

The 1989 population estimate of 34,270 $\pm$ 2360 (SE of estimate) is significantly higher than the July 1985 estimate (25,700 $\pm$ 2050 SE, McLean et al. 1986, $t'=2.726$; $t_{0.05[60]}=2.0$;) and the July 1982 estimate (9,393 $\pm$ 1054; Latour 1985, $t'=9.610$; $t_{0.05[39]}=2.023$).

The increase in muskox numbers (approximately 10% per year) at the same time as a decline in caribou furthers the concerns from Sachs Harbour that the muskoxen are competing with the caribou.

While we have no evidence to suggest that this is happening we do not fully understand the influences of high muskox densities and winter severity upon diet selection. Earlier research has shown that in the 1970s muskox and caribou were not competing for food or space on their summer ranges on northern Banks Island and there was little overlap in summer diet (Wilkinson et al. 1976). During severe winter conditions competition for limited snow-free feeding sites may increase. Documentation of annual variation in snow conditions, diet and feeding locations of caribou and muskoxen will be a research priority for the next few years.

RECOMMENDATIONS

1) Conduct a strip transect aerial survey in 1991 for caribou using the same methods as 1989. Initial coverage should be at 10% to be certain of detecting all higher density areas.

2) Monitor annual variation in weather on Banks Island and snow and icing conditions. Caribou and muskox winter feeding sites will also be examined.

3) Monitor body condition and age specific reproductive status of females from hunter-killed caribou and/or a collection in late fall.

4) The subsistence harvest of caribou in Sachs Harbour should be reduced to 150 animals annually. The only aspect of the commercial quota which should continue is the sports hunting (approximately 20 animals annually) and these should be taken from the 150.

5) Continue to monitor disease and parasite loads in muskox at commercial slaughters and in the high density area.

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Cecil Rilling (Inuvik Air Charters) and Perry Linton (Nahanni Air) capably flew the survey for us.

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Appendix A. Survey schedule and costs, Banks Island, NWT June 1989.

Date	Location	Hours Flown	Weather
21/06	Sachs Harbour (2 planes)	10.3(ferry)	overcast
22/06	stratum A	11.8	CAVU, 4°C
23/06	D, C9-12	19.0	CAVU, 8°C
24/06	C1-8, B8-9	12.3	ground fog on lines B9,C4 and C6.
25/06	B-1, B-2	6.7	fog in a.m.
26/06	B-2, E,M	15.6	CAVU, 18°C
27/06	TR	16.5	high scattered cloud, 11°C
28/06	E,M,P,D-2	27.0*	hi scattered, 14°C
COSTS (x$1000)	Air charters	30.0	
	Fuel (1988)	8.0	
	Barge (1988)	2.0	
	Fuel caching	15.0	
	Accommodation	6.0	
	Casual	2.0	
	Total	63.0	

* Includes 12 hours ferry time for 2 planes.

Appendix B. Number of caribou observed on transect on Banks Island, NWT. June 1989.

Str	Trans. Line	Area (km^2)	Left Observer Non-calf	Left Observer Calf	Right Observer Non-calf	Right Observer Calf	Total
A	1	28	0	0	0	0	0
	2	54	0	0	0	0	0
	3	90	0	0	0	0	0
	4	148	0	0	3	0	3
	5	168	0	0	0	0	0
	6	186	2	0	2	0	4
	7	226	6	0	1	0	7
	8	256	4	3	2	0	6+3
	9	252	13	0	2	0	15
Subtotal		1408	25	3	10	0	35+3

Str	Trans. Line	Area (km^2)	Left Observer Non-calf	Left Observer Calf	Right Observer Non-calf	Right Observer Calf	Total
B-1	1	42	0	0	0	0	0
	2	124	5	0	4	0	9
	3	101	0	0	1	1	1+1
	4	101	0	0	1	1	1+1
	5	96	0	0	1	0	1
	6	97	0	0	1	0	1
	7	92	5	2	2	1	7+3
	8	207	8	0	0	0	8
	9	207	1	0	0	0	1
Subtotal		1067	19	2	10	3	29+5

Str	Trans. Line	Area (km^2)	Left Observer Non-calf	Left Observer Calf	Right Observer Non-calf	Right Observer Calf	Total
B-2	1	44	0	0	0	0	0
	2	44	12	3	0	0	0
	3	43	13	3	2	0	15+3
	4	46	12	2	1	0	13+2
	5	47	2	0	1	1	3+1
	6	48	0	0	0	0	0
	7	49	1	0	6	1	7+1
	8	49	6	3	0	0	6+3
	9	49.5	12	5	8	3	20+8
	10	51	1	1	0	0	1+1
	11	53	0	0	7	7	7+7
Subtotal		523	59	17	25	12	84+29

Str	Trans. Line	Area (km^2)	Left Observer Non-calf	Left Observer Calf	Right Observer Non-calf	Right Observer Calf	Total
C	1	18	0	0	0	0	0
	2	96	0	0	0	0	0
	3	150	2	2	4	0	6+2
	4	162	0	0	2	0	2
	5	174	0	0	1	0	1
	6	165	1	0	0	0	1
	7	Not Flown					
	8	216	0	0	0	0	0
	9	207	0	0	0	0	0
	10	186	2	0	0	0	2
	11	168	3	0	0	0	3
	12	150	4	0	1	0	5
Subtotal		1692	12	2	8	0	20+2

Str	Trans. Line	Area (km^2)	Left Observer Non-calf	Left Observer Calf	Right Observer Non-calf	Right Observer Calf	Total
D-1	1	180	0	0	0	0	0
	2	162	6	3	2	0	8+3
	3	144	2	1	3	2	5+3
	4	42	2	0	5	0	7
	5	61	1	1	0	0	1+1
	6	84	7	3	9	1	16+4
	7	114	7	1	8	3	15+4
	8	99	5	2	2	2	7+4
	9	93	5	1	5	4	10+5
	10	87	5	0	0	0	5
	11	87	0	0	2	0	2
	12	90	3	0	0	0	3
	13	87	1	1	0	0	1+1
	14	78	0	0	0	0	0
	15	24	0	0	0	0	0
	16	12	0	0	0	0	0
Subtotal		1444	44	13	36	12	80+25

Str	Trans. Line	Area (km^2)	Left Observer Non-calf	Left Observer Calf	Right Observer Non-calf	Right Observer Calf	Total
D-2	1	Not flown					
	2	Not flown					
	3	65	0	0	4	1	4+1
	4	46	1	0	0	0	1
	5	47	0	0	3	2	3+2
	6	70.5	3	3	5	2	8+5
	7	72	5	2	5	5	10+7
	8	92	11	7	16	9	27+16
	9	77.5	9	6	11	6	20+12
	10	93	14	8	2	2	16+10
	11	81	3	0	4	1	7+1
Subtotal		676.5	46	26	50	28	96+54

Appendix C. Number of muskoxen observed on transect on Banks Island, NWT June 1989.

Str	Trans. Line	Area (km^2)	Left Observer Non-calf	Left Observer Calf	Right Observer Non-calf	Right Observer Calf	Total
A	1	27	8	1	0	0	0
	2	54	4	0	0	0	4
	3	90	16	1	1	0	17+1
	4	147	3	1	4	0	7+1
	5	168	27	3	53	6	80+9
	6	96	12	3	32	7	44+10
	7	103	62	11	35	6	97+17
	8	134	47	6	43	5	90+11
	9	224	46	8	24	3	70+11
Subtotal		1043	225	34	192	27	417+61

Str	Trans. Line	Area (km^2)	Left Observer Non-calf	Left Observer Calf	Right Observer Non-calf	Right Observer Calf	Total
B	1	42	0	0	0	0	0
	2	123	14	1	6	3	20+4
	3	189	40	5	19	3	59+8
	4	192	35	5	22	4	57+9
	5	192	27	3	35	4	62+7
	6	195	10	1	28	1	38+2
	7	179	43	6	25	2	68+8
	8	160	128	18	29	2	157+20
	9	80	3	0	12	0	15
Subtotal		1320	291	39	176	19	476+58

Str	Trans. Line	Area (km^2)	Left Observer Non-calf	Left Observer Calf	Right Observer Non-calf	Right Observer Calf	Total
C	1	0					
	2	49	0	0	6	0	6
	3	68	0	0	0	0	0
	4	88	21	1	17	2	38+3
	5	82.5	18	4	27	2	45+6
	6	70	0	0	0	0	0
	7	Not flown					
	8	74	10	2	1	0	11+2
	9	95	10	0	32	6	42+6
	10	124	11	2	16	2	27+4
	11	168	27	5	84	19	111+24
	12	150	63	9	15	4	78+13
Subtotal		968.5	160	23	198	35	358+58

Str	Trans. Line	Area (km^2)	Left Observer Non-calf	Left Observer Calf	Right Observer Non-calf	Right Observer Calf	Total
D	1	180	14	0	20	3	34+3
	2	162	18	5	7	2	25+7
	3	144	13	3	13	3	26+6
	4	136	12	5	24	6	36+11
	5	132	6	0	10	1	16+1
	6	130	0	0	65	9	65+9
	7	114	23	3	16	4	39+7
	8	100	8	1	5	0	13+1
	9	94	4	0	7	0	11
	10	88	1	0	16	1	17+1
	11	88	5	1	2	0	7+1
	12	90	8	2	10	0	18+2
	13	88	20	2	28	1	48+3
	14	78	33	3	25	5	58+8
	15	24	2	0	0	0	2
	16	12	9	0	12	1	21+1
Subtotal		1660	176	25	260	36	436+61

Str	Trans. Line	Area (km^2)	Left Observer Non-calf	Left Observer Calf	Right Observer Non-calf	Right Observer Calf	Total
E	1	46	24	1	9	2	33+3
	2	46	10	2	37	6	47+8
	3	46	7	0	27	6	34+6
	4	46	65	7	64	9	129+16
	5	46	14	0	42	12	56+12
	6	46	8	2	14	2	22+4
	7	46	13	2	6	2	19+4
	8	46	25	2	10	0	35+2
	9	46	22	2	17	3	39+5
	10	46	33	6	9	2	42+8
	11	46	19	7	13	3	32+10
	12	46	6	2	6	1	12+3
Subtotal		552	246	33	254	48	500+81

Str	Trans. Line	Area (km^2)	Left Observer Non-calf	Left Observer Calf	Right Observer Non-calf	Right Observer Calf	Total
M	1	52	16	0	13	0	29+0
	2	55	118	14	45	8	163+22
	3	58	90	8	89	16	179+24
	4	61	34	2	41	10	75+12
	5	54	37	6	31	6	68+12
Subtotal		280	295	30	219	40	514+70

Str	Trans. Line	Area (km^2)	Left Observer Non-calf	Left Observer Calf	Right Observer Non-calf	Right Observer Calf	Total
P	1	96	31	4	48	2	79+6
	2	98	37	6	32	3	69+9
	3	99	31	3	20	3	51+6
	4	102	28	2	76	3	104+5
	5	98	49	8	11	0	60+8
	6	82	21	0	34	0	55
	7	69	16	3	34	3	50+6
Subtotal		644	213	26	255	14	468+40

Str	Trans. Line	Area (km^2)	Left Observer Non-calf	Left Observer Calf	Right Observer Non-calf	Right Observer Calf	Total
TR	1	44	26	3	13	2	39+5
	2	49	51	9	28	6	79+15
	3	55	52	11	73	11	125+22
	4	61	54	11	50	8	104+19
	5	66	10	2	27	2	37+4
	6	72	40	6	23	4	63+10
	7	78	11	0	59	8	70+8
	8	84	61	17	74	10	135+27
	9	85	147	27	119	15	266+42
	10	85	62	10	46	5	108+15
	11	84	59	11	20	2	79+13
	12	86	61	9	52	5	113+14
	13	87	38	5	46	5	84+10
	14	89	40	3	27	5	67+8
	15	96	19	2	109	11	128+13
	16	105	65	12	51	5	116+17
	17	86	61	9	73	13	134+22
	18	42	15	0	19	6	34+6
	19	112	63	5	104	17	167+22
	20	108	64	13	61	7	125+20
	21	106	88	10	95	14	183+24
	22	101	59	11	43	9	102+20
	23	86	68	16	41	8	109+24
	24	61	38	8	78	15	116+23
	25	37	10	4	12	3	22+7
	26	13	8	0	9	2	17+2
Subtotal		1982	1270	214	1352	198	2622+412

APPENDIX D. Statistical procedures used to calculate the Student's t-test (Gasaway et al. 1986).

The Student's t-test is used to make two types of tests, one-tailed and two-tailed tests, that detect if changes in population size are statistically significant. Two-tailed tests are used to detect a change, if it occurred, in either direction, i.e., increase or decrease. One-tailed tests detect change in a specific direction.

a) Hypotheses for a one-tailed test to test for a decrease in population size are:

H_o: The population size has not decreased, i.e. $T_1 \leq T_2$
H_a: The population size has decreased, i.e. $T_1 \geq T_2$
Reject H_o in favour of H_a if $t' \geq$ than t_{table}.

Calculated t-statistic is:

$$t' = \frac{T_1 - T_2}{\sqrt{V(T_1) + V(T_2)}}$$

where t' = calculated t-statistic
T_1 = population estimate at year 1
T_2 = population estimate at year 2
$V(T_1)$ = variance of T_1 population estimate
$V(T_2)$ = variance of T_2 population estimate

An estimate of the number of degrees of freedom (v_t) associated with the test statistic, t', is calculated as:

$$v_t = \frac{[V(T_2) + V(T_1)]^2}{\frac{V(T_2)^2}{v_{T2}} + \frac{V(T_1)^2}{v_{T1}}}$$

where v_t = degrees of freedom associated with the test statistic, t'
v_{T1} = degrees of freedom of T_1 population estimate
v_{T2} = degrees of freedom of T_2 population estimate

b) Hypotheses for a one-tailed test to test for an increase in population size are:

H_o: The population size has not increased, i.e. $T_1 \geq T_2$
H_a: The population size has increased, i.e. $T_1 < T_2$
Reject H_o in favour of H_a if $t' \geq$ than t_{table}.

Calculated t-statistic is:

$$t' = \frac{T_2 - T_1}{\sqrt{V(T_1 + V(T_2)}}$$